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Wear Performance of Ti Based Powders Coating on SS 304 by PVD Method

M. Shunmuga Priyan*, K. Santhosh, M. A. Sivaraman, S. Subith, M. Sunil

Department of Mechanical Engineering, Loyola Institute of Technology & Science, Thovalai, Tamil Nadu - 629302, India.

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Abstract

The PVD techniques range over a wide variety of applications from decorative, to high temperature superconducting films. The thickness of the deposits can vary from angstroms to millimeters. A very large number of inorganic materials—metals, alloys, compounds, and mixtures—as well as some organic materials can be deposited using Physical vapour Deposition (PVD) technologies. Traditionally, the term hard coatings refer to the property of high hardness in the mechanical sense with good tribological properties. The analysis of PVD coating on stainless steel has been carried out. The objectives of the coating are to check the properties and wear performance of coated and uncoated materials. For this project, we selected stainless steel discs as a substrate; among those three of them are coated with Ti based powder deposited by using PVD method. While after the coating process has been completed the roughness of each coated and uncoated material has been carried out. Ensure that the weight of the materials should be checked before the wear test is to be performed. Now the wear performance of the coated and uncoated materials should be carried out, in order to achieve the low co-efficient of friction in coated materials than the uncoated materials by using Pin-On-Disc apparatus having Tribological Data Acquisition System. Again the weight of the materials should be checked to determine the weight loss of each material.

Introduction

The introduction of PVD thin film coatings for cutting tools in the metal cutting industry is one of the main success stories in the industrial application of modern coating technology. PVD coatings are hard and wear resistant and consequently protect punches and forming tools against abrasive wear significantly extending the lifetime of the tools. It is performed to check the brittleness, fatigue test, hardness and tool life. The brittleness and fatigue test is carried out by macro and nano impact test. Here they use cemented carbide as substrate and it was coated by Ti-Al-N and TiN with mono and multi layer [1] also being used cemented carbide as tool insert with Ti-Al-N coating for turning of hot rolled SAE 4140H steels [2]. Roughness values were also lower for surface machined with Al-Ti-Si-N and Al-TiN tool coating. Al-Ti-Si-N and Al-TiN tool coating give best performance than other two coating in better tool flank wear, less tangential cutting force and less part roughness [3]. It has studied that Scratch adhesion characteristics of PVD Ti-Al-N deposited on high speed steel, cemented carbide and PCBN substrates [4]. Investigations on the Assessment of gradient and nano gradient PVD coatings behaviour under erosive, abrasive and impact wear conditions [5-6], and also study on the fatigue behaviour of an AISI 316L stainless steel coated with a PVD TiN deposit. The effect of a TiN coating on the fatigue properties of an AISI 316L stainless steel has been investigated. The effects of work materials on the wear improvement of coated tools by comparing uncoated and TiC coated carbide tools [7]. The experimental results revealed the effectiveness of TiC coating in machining carbon 1045 grade, decreasing tool wear rates by [8] half an order magnitude. Rogante, conducted the comparative study on TiC–TiN coated and uncoated inserts when machining of normalized medium carbon steel in dry cutting process. The performance of the modified Ti-Al-N coatings was prepared by pulsed D.C. magnetron sputtering process [9]. Coating prepared with pulsed sputtering process improves the hardness and also offers high wear resistance in turning process [10-12]. The experimental results revealed that multilayer TiC + Al2O3 + TiN coated tool exhibits higher performance by reducing cutting forces while machining when compared to uncoated tools [13] TiN, TiC, TiCN and Ti-Al-N and are the common used Ti-base hard coating. TiN possesses some very useful properties, despite its relatively lower hardness. The formation of a stable Al2O3 layer on Ti-Al-N coating endowed the Ti-Al-N coated tool with higher resistance to abrasive wear and crater wear and makes Ti-Al-N coated tools preformed better than TiCN coated tool and had longer tool life [14]. The objectives of the coating are to check the properties and wear performance of coated and uncoated materials. For this work, we selected stainless steel discs as a substrate; among those three of them are coated with Ti based powder deposited by using PVD method and wear determined with help of Pin-On-Disc method.

Experimental

Selection of the work piece

The typical pin specimen is cylindrical or spherical in shape. Typical cylindrical and spherical pin specimen's diameters range from 2 to 10 mm. The typical disk specimen diameters range from 30 to 100 mm and have a thickness in the range of 2 to 10 mm.

Typical compositional ranges for grade 304 stainless steels are given in Table 1 and typical mechanical properties for grade 304 stainless steels are given in Table 2.

Corresponding author. Tel.: +91-948888770,
E-mail address: iampriyan25@gmail.com

Table 1: Typical compositional ranges of grade 304 stainless steels

Grade Wt.%	C	Mn	Si	P	S	Cr
304	0.08	2.0	0.75	0.045	0.030	20.0

Table 2: Typical mechanical properties of grade 304 stainless steels

Grade Wt.%	C	Mn	Si	P	S	Cr
304	0.08	2.0	0.75	0.045	0.030	20.0

Experimental setup of PVD

PVD is the other major process used to produce cutting tool coatings. In PVD, the coating is deposited in a vacuum. The metal species of the coating, obtained via evaporation or sputtering, reacts with a gaseous species (nitrogen or ammonia, for example) in the chamber and is deposited onto the substrate. Because PVD is a low-pressure process, the coating atoms and molecules undergo relatively few collisions on their way to the substrate. PVD is therefore a line-of-sight process that requires moving fixtures to ensure uniform coating thickness .The main difference between PVD and CVD is the former's relatively low processing temperature of PVD which is 500ºC (930ºF).This lower processing temperature resulted in multiple benefits for PVD coatings. PVD coatings are essentially free of the thermal cracks that are common in CVD coatings. In PVD, processing temperatures are low enough that eta-phase formation is eliminated, allowing deposition of PVD coatings on sharp edges. Ability to coat sharp edges is also enhanced by PVD coatings' relative thinness versus CVD. Coating microstructures depend on processing conditions.

Pin-on-disc apparatus

This test method describes a laboratory procedure for determining the wear of materials during sliding using a pin-on-disk apparatus shown in Fig 1. Materials are tested in pairs under nominally non-abrasive conditions. The principal areas of experimental attention in using this type of apparatus to measure wear are described. The coefficient of friction may also be determined.

Figure 1: Experimental setup of Pin-On-Disc apparatus

Table 3: Specification of pin-on-disc apparatus

Normal Load	0.1 to 20 N
Friction Force Range	0 to 50 N
Contact Configurations	Pin on Disc, Ball on Disc
Disc Diameter	75 mm
Track Radius	0 to 35 mm
Rotational Speed	2 to 200 rpm
Sliding Velocity	0.007 to 0.7 m/s
Motor	190 W dc

Surface roughness test

Surface roughness is a measure of the texture of surface. It is quantified by the vertical deviation of real surface from its ideal form. If these deviations are great, the surface is rough, if they are small, the surface is smooth. Roughness is typically considered to be the high-frequency, short-wavelength component of a measured surface. Surface roughness of all specimens was evaluated before and after wear test in terms of arithmetic average value (Ra) by Taylor Hobson Non-contact roughness tester, (Talysurf CCI 6000). In practice, it is often necessary to know both the amplitude and frequency to ensure that a surface is fit for purpose.

Results and Discussion

Wear samples

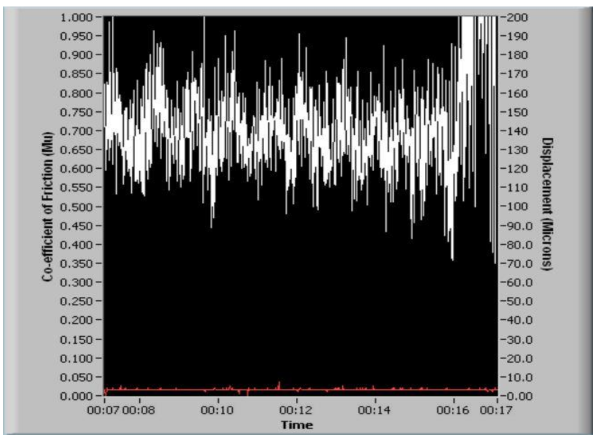
The study wear of materials, we must simulate the process of wear in a controlled manner and study the effect on different samples with the same test conditions at shown in fig 2. One way to perform the wear test is with a ball or pin on disk Tribometer (ASTM G99 or G133). With this test, a reference sample is mounted on a rotating stage and a pin or ball (object of study) comes in contact with the Sample surface with a known applied load. Typically the interest of wear would be on the reference sample at the bottom but another alternative testing method is to evaluate the wear of the ball or pin tip. In this case, while the reference sample rotates, the contact pressure gradually wears the ball or the pin.

Figure 2: Shows of Coated and Uncoated materials

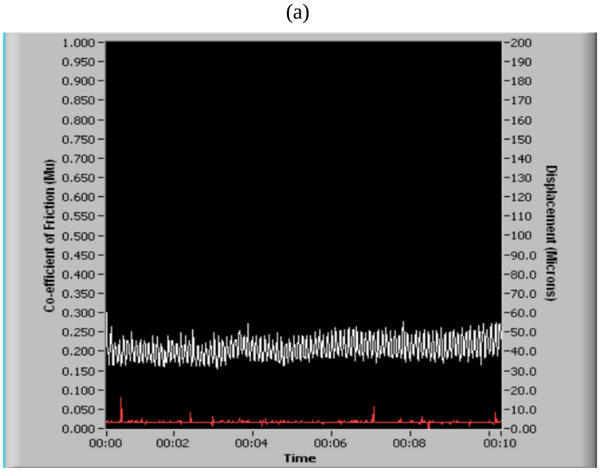
Coefficient of friction

The low co-efficient friction for Ti based coated material compare to the uncoated material. The co-efficient of friction value is measured during machining of coated and uncoated material by using Pin-On-Disc apparatus. In theoretical co-efficient of friction is measured by the value of frictional force and load. But in this research we are using Pin-On-Disc apparatus for measuring co efficient of friction. So, the co-efficient of friction graph is taken by using Tribology Data Acquisition System. The co-efficient of friction of coated and uncoated materials are represented in the below shown figures 3. In the above shown online graphical representation of uncoated material, the co- efficient of friction is increases with increase in time up to 4mins at a constant load of 3kg and the sliding speed of disc at 2.1m/s. From the illustration, uncoated material is produced high co-efficient of friction due to applied load with dry sliding condition. The surface of the uncoated material is more plastic deformation in which applied load at ambient condition. Metal to metal contact is more surface area at during the sliding condition.

In the above shown online graphical representation of Ti-Al-Cr-N coated material. From the illustration, the co-efficient of friction is low compared with uncoated material, and the co-efficient of friction of Ti-Al-Cr-N is slightly low compared with Ti-Al-N.



(a)



(b)

Figure 3: Shows COF of uncoated (a) and coated (b) materials

The co-efficient of friction of the Ti-Al-Cr-N is low due to applied load with dry sliding condition. The surface of Ti-Al-Cr-N is low plastic deformation in which applied load at ambient condition compared with uncoated and Ti-Al-N material and also the metal to metal contact is less surface area at during the sliding condition. From the illustration, the co-efficient of friction of Ti-N is very low compared with uncoated material, Ti-Al-N and Ti-Al-Cr-N at a constant load of 3kg and the sliding speed of disc at 2.1m/s under the dry sliding condition. The surface of Ti-N material is low plastic deformation in which applied load at ambient condition and also the metal to metal contact is low surface area compared with uncoated, Ti-Al-N and Ti-Al-Cr-N materials at during the sliding condition.

Weight loss

Weight loss of material is calculated by using the value of weight of the material before the wear test and weight of the material after the wear test as shown in Table 4. Wear performance of the coated and uncoated materials is analysis by using the weight loss value of each material of weight loss plot in graph fig 4.

Table 4: Weight loss comparison

Materials	Weight of material before wear test (g)	Weight of material after wear test (g)	Weight Loss (g)
Uncoated	184.44	181.90	2.54
Ti-Al-N	186.62	184.74	1.88
Ti-Al-Cr-N	187.13	186.60	0.53
Ti-N	188.25	187.90	0.35

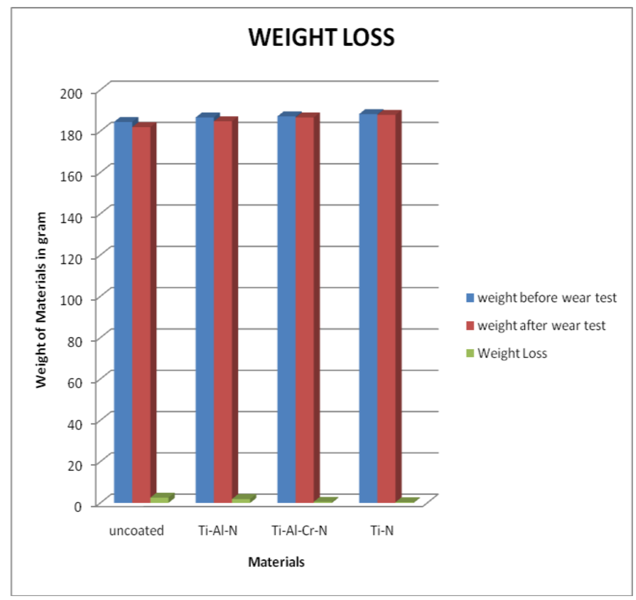


Figure 4: Weight loss chart at ambient conditions

Micro-Hardness

Micro-hardness was tested at various places on the coating surface in Wolpert Wilson equipment, model 402 MVD. A load of 50g was employed for a dewell time of 10sec. Hardness at the surface of the coated and the uncoated SS material was found out by using Micro hardness tester. Hardness values of the uncoated and coated specimen shown in fig 5.

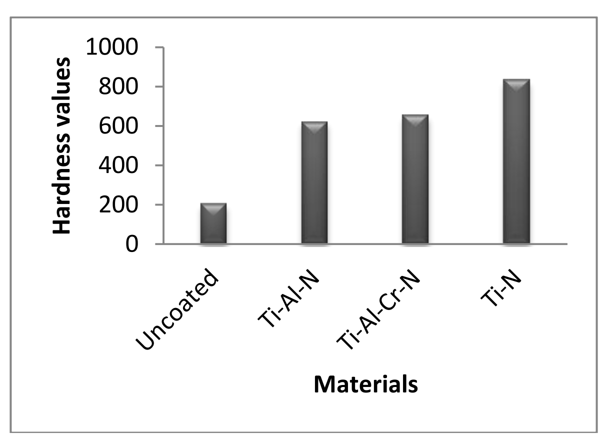


Figure 5: Microhardness graph plot between coated and uncoated materials

Surface Roughness

Surface Roughness of the uncoated and coated was found out by using Taylor Hobson surface roughness tester. Normally roughness value was increased on the coated and uncoated specimen due to metallurgical contact on both surfaces and dry sliding condition will occur, produced high roughness value on a materials. Traditional surface finish analysis consists mainly studying the surface texture, consisting of roughness and hardness as shown in Fig 6.

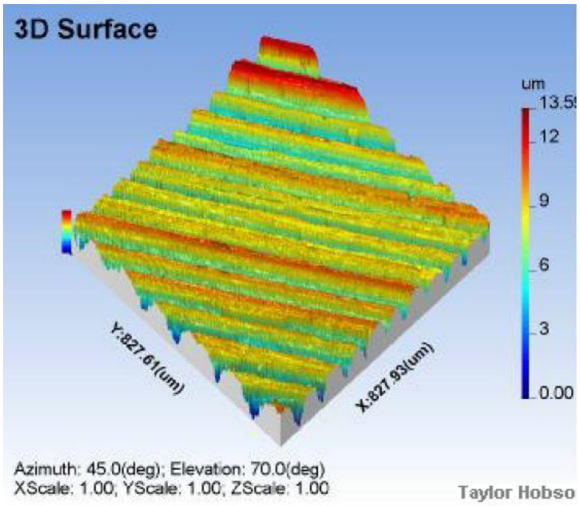


Figure 6: 3D Surface roughness for uncoated specimen

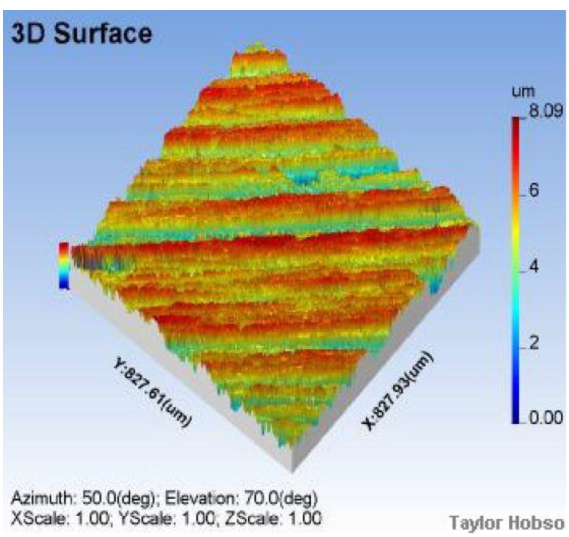


Figure 7: 3D Surface roughness for coated specimen

Figure 7 shows the profile traces of coated material of different initial surface roughness. Only the distance between the predominant peaks rather than the average roughness has a significant effect on the percentage of metallic contact. As the roughness increases, the distance between predominant peaks increases. Roughness values of uncoated and coated material (before and after wear test).

Conclusions

A study was under taken to establish the wear behaviour of PVD coating of Ti-Al-N, Ti-Al-Cr-N and Ti-N on stainless steel substrate. Three compositions of Ti-Al-N, Ti-Al-Cr-N and Ti-N were used and the results were compared.

1. When compared to the stainless steel (uncoated) material, there is an increase in hardness.
2. When compared to the uncoated material, there is an increase in hardness of coated materials.
3. Adhesive wear was measured by Pin-on-Disc apparatus. The results suggest that the coefficient of friction and wear rate decrease at constant speed, load and time. (For both coated and uncoated materials).
4. It is finally concluded that Ti-N coated in the stainless steel substrate reduces coefficient of friction and wear rate of moving parts.

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